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ASSESSMENT ON MECHANICAL PROPERTIES OF DUCTILE CAST IRON BY FORMULATING EMPIRICAL EQUATIONS

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ABSTRACT

In this work an attempt is made to assess the mechanical properties of SG iron by formulating empirical equations to determine the ingot diameter (solidification cooling rate) and vice versa for a given chemical composition. Five samples were produced by taking different ingot diameter to cover wide range of solidification cooling rate. The mechanical properties are noted. It was observed that, the mechanical properties such as Ultimate Tensile Strength and Yield Strength are decreasing as the ingot diameter is increasing. The % elongation is increases as the ingot diameter increases. It was also observed that the hardness value decreases as the ingot diameter increases. By using these relations an attempt is made to formulate empirical equations, which can give the desired ingot diameter (solidification cooling rate) for a given mechanical properties and vice versa. By applying these equations, the manufacturer can easily assess what should be ingot diameter to obtain the desired mechanical properties and vice versa. Hence the time required for the manufacturer to decide the manufacturing process parameters can be reduced.

KEYWORDS: Solidification Cooling Rate, SG Iron, Mechanical Properties

INTRODUCTION

Cast iron has a long and illustrious history and the five types of cast iron produced commercially today are i) White cast iron ii) Malleable cast iron iii) Grey cast iron iv) Spheroidal graphite iron or ductile iron v) Compacted cast iron. The development in the late 1940's after the second world war of an iron that was ductile as cast has revolutionized the concept of cast iron [1, 2]. SG iron has been used to replace cast steel because of its many advantageous properties such as higher strength to weight ratio, higher toughness, damping capacity, better wear resistance, better fluidity, lower melting point, better hot workability and hardenability [1, 3-6].

Much of the annual production of ductile iron is in the form of ductile iron pipes, used for water and sewer lines. Ductile iron is specifically useful in many automotive components, where strength needs surpass that of aluminum but do not necessarily require steel. Other major industrial applications include off-highway diesel trucks, agricultural tractors, and oil well pumps [1, 3]. Several researchers have made a study on Microstructure, mechanical properties and nodularity of SG iron. [9, 10] they have correlated the nodularity with the mechanical properties. Some researchers have worked on solidification cooling rate of SG iron and correlated it with the nodularity and mechanical properties [8, 12]. In this work author has made an attempt to correlate the mechanical properties and solidification cooling rate by using ingot with different diameters like 25, 35, 45, 55 and 65mm to cover wide range of solidification cooling rate. The result obtained from the experimentation is used to formulate generalized empirical equations for different mechanical properties of the SG iron. By using these equations we can easily assess the mechanical properties for a given ingot diameter and vice versa.

EXPERIMENTAL PROCEDURE

Materials, Chemical Composition and Melting Practices

92.13% of the charge was pig iron with 3.610% of C and 1.740% of Si and 0.002% of Mg. The materials were melted in a basic high frequency induction furnace. The molten metal was poured into the mould cavity using ladle sandwich technique. The detailed chemical composition used in the present study is given in the table below

Table 1: Chemical Composition of SG Iron

Fe%	C%	Si%	Mn%	P%	S%	Mg%	Al%
92.13	3.610	1.740	0.410	0.039	0.023	0.002	0.040

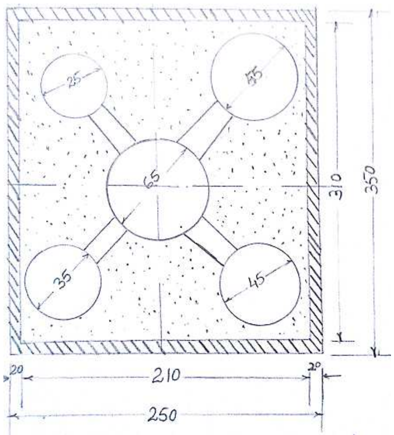

Figure 1: Sectional Plan in the Sand Mould Showing the Distribution of Cavities for Simultaneous Casting with Different Ingot Diameters (Dimensions in mm)

Casting

In the sand casting procedure, the ingots were cast vertically producing 5 cylindrical ingots as shown in the figure 1. The ingot diameter being 25, 35, 45, 55 and 65mm with a common height of 200mm.The variety of diameter in the sand mould aimed at covering a wide range of solidification cooling rates.

Hardness Tests

Hardness measurements were carried out using hardness tester namely Brinell.

Tensile Tests

Tensile properties were obtained from the standard test specimens, which were machined to a gauge diameter of 5mm and gauge length of 25mm. A motar driven tensiometer machine of (type w) was used. It was carried out at room temperature and at a strain rate of 0.0004 per second.

RESULTS AND DISCUSSIONS

Hardness Property

The table 2 shows the mechanical properties of SG iron. From the table2, it is observed that there is variation in the hardness value with the ingot diameter. There is a monotonic decrease in the hardness value with the increase in the ingot diameter. It indicates that the ingot diameter is inversely proportional to hardness value.

i,e Ingot diameter α 1/ Hardness Value

Tensile Properties

From the table 2, it can be observed that, there is a decrease in the ultimate tensile strength and yield strength with the increase in the ingot diameter. It indicates that the ingot diameter is inversely proportional to ultimate tensile strength and yield strength.

i,e Ingot diameter α 1/ Ultimate Tensile Strength

i,e Ingot diameter α 1/ Yield Strength

It can also be observed from the table 2 that, % elongation is increasing with the increase in the ingot diameter. It indicates that the ingot diameter is directly proportional to % elongation.

i,e Ingot diameter α 1/ % Elongation

Table 2: Mechanical Properties of SG Iron

Ingot Diameter (mm)	Ultimate Tensile Strength(Mpa)	% Elongation (%)	Hardness (BHN)	Yield Strength (Mpa)
25	450.17	18.32	162	293.16
35	447.43	18.72	157.5	291.40
45	444.68	19.14	153	289.22
55	441.94	19.54	148.5	286.60
65	439.20	19.96	144	283.56

From the literature [10], it was observed that Mechanical properties of SG iron mainly dependent on the nodularity. It was even observed that the nodularity depends on the solidification cooling rate [8]. Here in this experiment, a number of ingot diameters were taken to cover wide range of solidification cooling rate. In this work author has an intension to formulate a generalized empirical equation for the various mechanical properties of ductile cast iron. Here interpolation of the data collected from the experimentation is used to formulate the equations. These developed generalized empirical equations for the various mechanical properties of SG iron are restricted only for this given chemical composition.

Equations

By applying these equations, the manufacturer can easily identify what should be ingot diameter to obtain the given mechanical properties and vice versa.

Ultimate Tensile Strength

$$f(x) = 0.00025x^2 - 0.289x + 457.768 \quad (1)$$

Where,

$f(x)$ is the ultimate tensile strength for a given ingot diameter x

From the above eqn(1), one can easily find out the desired ingot diameter (Solidification cooling rate) for a given ultimate tensile strength and vice versa.

Yield Strength

$$f(x) = 7.33\times 10^{-5} x^3 - 9.79\times 10^{-3} x^2 + 0.212x + 292.833 \quad (2)$$

Where,

f (x) is the Yield strength for a given ingot diameter x

From the above eqn (2), one can easily find out the desired ingot diameter (Solidification cooling rate) for a given Yield strength and vice versa.

% Elongation

$$f(x) = -0.00000666x^3 + 0.0008x^2 + 0.01017x + 17.67 \quad (3)$$

Where,

f (x) is the % Elongation for a given ingot diameter x

From the above eqn (3), one can easily find out the desired ingot diameter (Solidification cooling rate) for a given % Elongation and vice versa.

Hardness

$$f(x) = 173.25 - 0.45x \quad (4)$$

Where,

f (x) is the Hardness value for a given ingot diameter x

From the above eqn (4), one can easily find out the desired ingot diameter (Solidification cooling rate) for a given Hardness value and vice versa.

By using these equations we can easily assess the mechanical properties for a given ingot diameter and vice versa.

CONCLUSIONS

From the experimentation it is found that solidification cooling rate is correlated to mechanical properties. This has been confirmed by taking various ingot diameters.

The author developed equations representing the correlation of ingot diameter with the various mechanical properties such as Ultimate Tensile Strength, Yield Strength, % Elongation and Hardness. These equations holds good only for a given chemical composition. By applying these equations, the manufacturer can easily identify what should be ingot diameter to obtain the given mechanical properties and vice versa. Hence the time required for the manufacturer to decide the manufacturing process parameters can be reduced.

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